The PHOS Detector at ALICE*

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Abstract. The ALICE experiment at CERN is aimed to explore QCD matter created in heavy-ion collisions at LHC energies. The electromagnetic calorimeter PHOS is designed for ALICE to detect and identify photons in extremely high particle-densities and thus to reach to the early stage of collisions via photonic signals. The first module out of five is now under assembly. The brief overview of design and status are described in this paper.

Keywords: Lead-tungstate crystal (PWO), Avalanche photo-diode, EM-calorimeter, ALICE.
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INTRODUCTION

The RHIC experiments at BNL have revealed many intriguing properties of nuclear matter created in Au+Au collisions at $\sqrt{s_{NN}}$=200GeV. The Large Hadron Collider (LHC) colliding lead-ions at energies up to $\sqrt{s_{NN}}$=5.5TeV opens new opportunities for these studies toward characterization of the strongly interacting partonic matter named ***perfect liquid*** at RHIC, at much higher temperature and energy-densities, as closing more on the primordial Universe. Measuring thermal photons is the key to exploring QCD nature of the matter. Hard-scattering becomes predominant at these energies and thus energetic direct photon is another significant physics object.

THE PHOS DETECTOR

The PHOS is a high-granularity and high-resolution electromagnetic calorimeter comprising 17,920 detector elements made of newly developed lead-tungstate ($PbWO_4$) crystals. They are distributed in five identical modules and placed in a magnetic field behind cylindrical detectors at a distance of 4.4m from the interaction point as shown in Fig.1. The PHOS covers the pseudo-rapidity range $-0.12<\eta<+0.12$ with an azimuthal acceptance of $\Delta\phi=100°$.

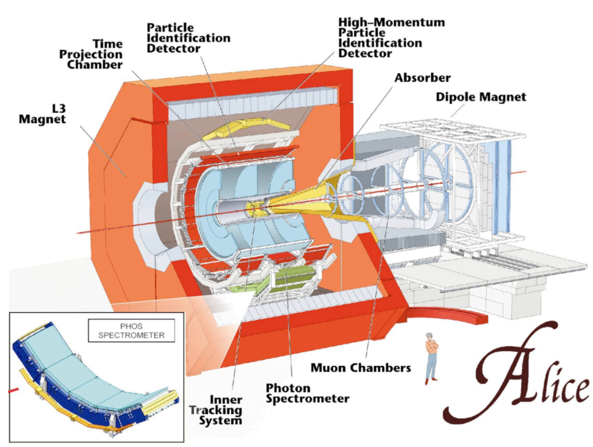

FIGURE 1. The ALICE experiment and the PHOS in the insert

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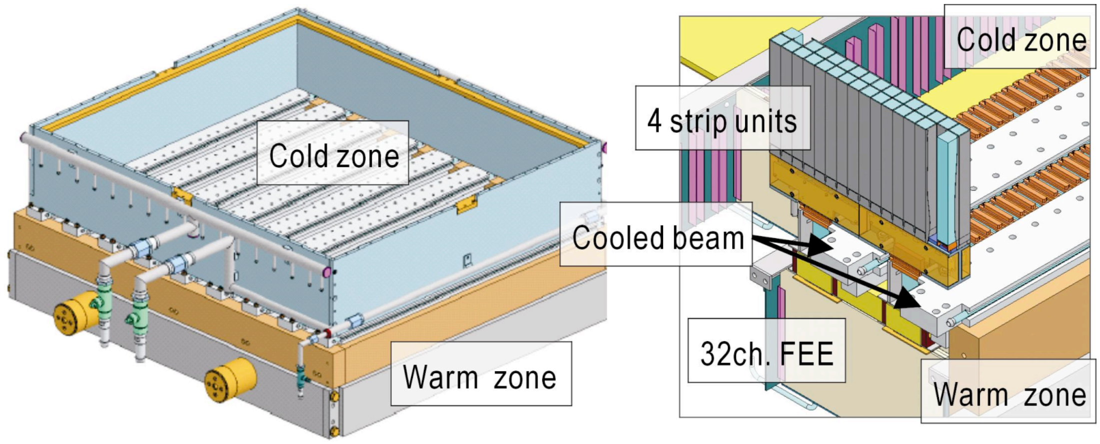

FIGURE 2. Mechanical structure overview of the PHOS module

The PWO crystals of 2.2×2.2×18cm^3, corresponding to 20 radiation length in depth, are produced by *North Crystal co*. in Russia. More than 9,000 crystals have been accepted by Kurchatov Institute and delivered to CERN. PWO is a fast scintillating crystal (τ_{decay}~5ns for the largest component) with a short radiation length (0.9cm) and the smallest Moliere radius (2.0cm) in inorganic crystals so far developed. These are strong advantage for a highly segmented calorimetry to apply in high particle densities, however, the light yield is one thousandth of those of NaI(Tl) and the yield depends on temperature with a large negative coefficient of -2%/deg. It turns out that a high-efficiency and low-noise photon sensor as well as a thermo-stabilized container system which cools down and keeps the crystals at a constant temperature with an accuracy of ±0.1° C, are crucially important for a high-resolution calorimetry.

A matrix of 56 by 64 detector elements, 112 front-end-electronics (FEE) cards and 8 trigger-regional-units (TRU) cards are embedded in each module. The detector element is composed of a PWO crystal glued on an Avalanche Photo-Diode (Hamamatsu S8664-55) coupled to a JFET charge-sensitive preamplifier produced in Japan. Each APD will be operated at a moderate gain M=50 applying a nominal bias voltage of 350-400V by a precise bias regulator of 0.2V step. The charge sensitive preamplifier amplifies the signal up to 5V at the maximum with a sensitivity of 0.8V/pc. The RMS noise of the preamplifier is evaluated to be around ENC=200-500e. To increase the light yield and to reduce thermal noise in the photon sensor, the detector elements will be operated at -25° C. The container is, therefore, thermally separated into two volumes; the cold zone on top part where the detector elements are placed and the warm zone underneath for electronics as shown in Fig.2. A row of 8 elements forms a strip unit, and 4 strip units in two rows are mounted on cooled metal beams in the cold zone. They are read out with a single FEE card placed in the warm zone. The interconnection is made by 4 thin flat cables through thermal insulator. On the top of each module, a LED monitoring system and a 128×56 pad-chamber vetoing charged particles built in Russia are mounted. Five modules mounted on a cradle built in Czech are installed in the ALICE spectrometer under the TOF barrel. More details of detector component and latest test results with the PHOS-256 prototype (a 16x16 crystal matrix) can be found in [1-2].

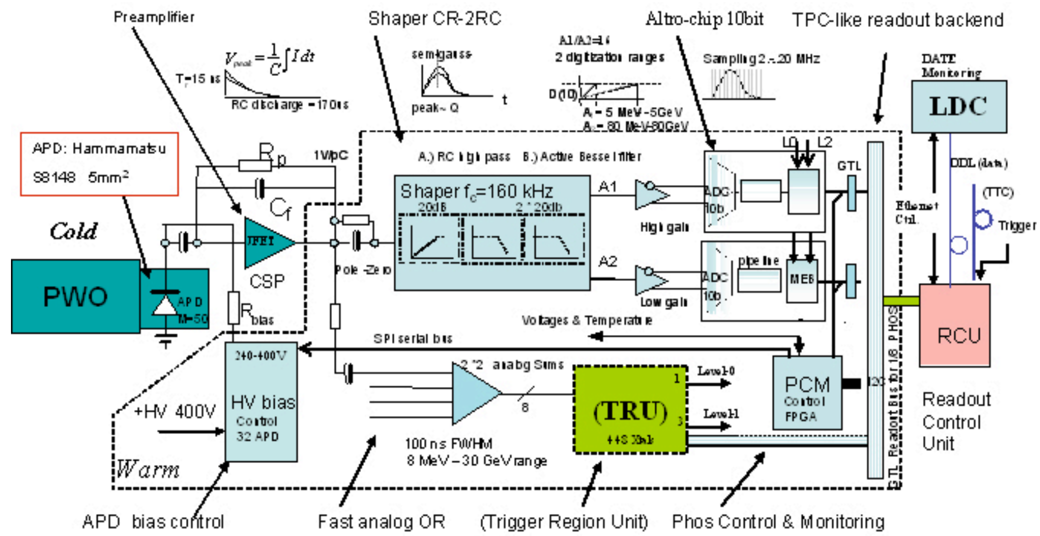

FIGURE 3. Overview of the PHOS Front-End-Electronics embedded in the module

Each FEE card contains 32-channel readout electronics of shaper/digitizer, 32-channel remote-controlled bias controller and communication/data-link ports. The CR-2RC shaper with the time constant of 1μs produces semi-gaussian dual-outputs A1 and A2 in Fig.3 with the gain ratio of 1 to 16. Both outputs are digitized with dual 10-bits ALTRO-16 chips at the sampling rate selectable between 2 and 10 MHz. Combining the both digitized data offline, the FEE covers a 14-bits dynamic range from 5 MeV to 80 GeV with a timing resolution of about 1ns. Analog sum information of 2×2 adjacent channels is transmitted to the TRU to form the level-0 and level-1 trigger signals, and whenever a trigger sequence is received, the readout-control-unit (RCU) reads data from all event-buffers embedded in the ALTRO chips and transmits them to the local-data-concentrator (LDC) of DAQ via the 200 Mbit/s optical link. The mass-production for the first FEE is underway in China. More details can be found in [3].

SUMMARY

The PHOS is a high-granularity and high-resolution electromagnetic calorimeter based on the latest technologies of inorganic crystallization process, photon sensor, electronics, and communication. Each detector element is designed for photon measurements in a wide energy range from 5 MeV up to 80 GeV with an excellent energy resolution of 3%/√E[GeV] as well as a fine timing resolution of ~1ns that is essential to reduce (anti-)neutron contamination in photonic spectra. The first module is now under assembly at CERN and will be ready for calibration in middle 2006.

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